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# Guidelines for Characterizing "OAM"
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## Abstract

As the IETF continues to produce and standardize different Operations, Administration, and Maintenance (OAM) protocols and technologies, various qualifiers and modifiers are prepended to the OAM abbreviation. While, at first glance, the most used appear to be well understood, the same qualifier may be interpreted differently in different contexts. A case in point is the qualifiers "in-band" and "out-of-band" which have their origins in the radio lexicon, and which have been extrapolated into other communication networks. This document recommends not to use these two terms when referring to OAM.

This document considers some common qualifiers and modifiers that are prepended, within the context of packet networks, to the OAM abbreviation and lays out guidelines for their use in future IETF work.

This document updates RFC6291 by adding to the guidelines for the use of the term "OAM". It does not modify any other part of RFC6291.

## Status of This Memo

## Copyright Notice



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## 1. Introduction

It is not uncommon for historical and popular terms to have nuances in how they are interpreted or understood. This was, for example, the case with the abbreviation for Operations, Administration, and Maintenance, "OAM", and [RFC6291] provides guidelines for its use as well as definitions of its constituent parts.

Characterizations or qualifiers for "OAM" within packet networks often encounter similar problems of interpretation, such as with the adjective phrases "in-band" and "out-of-band" (Section 2). This document considers some common qualifiers and modifiers that are prepended to the OAM abbreviation, and lays out guidelines for their use in future IETF work to achieve consistent and unambiguous characterization (Section 3). While this document introduces new terminology, it is does not update or change the meaning of terminology found in existing RFCs.

## 2. In-Band and Out-of-Band OAM

Historically, the terms "in-band" and "out-of-band" were used extensively in radio communications as well as in telephony signaling [RFC4733]. In both these cases, there is an actual "Band" (i.e., a "Channel" or "Frequency") to be within or outside.

While those terms, useful in their simplicity, continued to be broadly used to mean "within something" and "outside something", a challenge is presented for IP communications and packet-switched networks (PSNs) which do not have a "band" per se, and, in fact, have multiple "somethings" that OAM traffic can be carried within or outside. A frequently encountered case is the use of "in-band" to mean either In-Data-Packet or on-path.

There are many examples of "in-band OAM" and "out-of-band OAM" in published RFCs. For instance, the term "in-band" appears in both Virtual Circuit Connectivity Verification (VCCV) [RFC5085] and OAM for Deterministic Networking (DetNet) [RFC9551]. While the context in each of these documents is clear, the term carries different meanings in each case. These two examples, as well as other examples of uses of the term "in-band" in other documents are described in Appendix A.

Generally speaking, within the IETF, the terms "in-band" and "out-of-band" cannot be reliably understood consistently and unambiguously. Context-specific definitions of these terms are inconsistent and therefore cannot be generalized. More importantly, the terms are not self-defining to any further extent and cannot be understood by someone exposed to them for the first time, since there is no "band" in IP.

While interpreting existing documents, it is important to understand the semantics of what the term "band" refers to, and to be more explicit if those documents are updated. This document does not change the meaning of any terms in any prior RFCs.

## 3. Terminology and Guidance

### 3.1. Recommendation

This document recommends avoiding the terms "in-band" and "out-of-band" when referring to OAM. Instead, it encourages the use of more fine-grained and descriptive terminology. The document also presents alternative terms and definitions for use in future IETF documents referencing OAM, without precluding the use of other precise, descriptive terms that do not rely on the "-band" convention.

The terminology presented in this section classifies OAM according to three criteria: whether it operates in an active, passive, or hybrid mode (Section 3.2); whether it follows the same path as data traffic (Section 3.3); and whether it receives the same treatment as data traffic (Section 3.4).

### 3.2. Active, Passive, and Hybrid OAM

[RFC7799] provides clear definitions for active and passive performance assessment, enabling the construction of metrics and methods to be described as either "Active" or "Passive". Even though [RFC7799] does not explicitly use these terms as modifiers of "OAM", they are widely used in practice and are included here for clarity. The terms "Active", "Passive" and "Hybrid", as described below, are consistent with [RFC7799]. This document does not update or change the terms of [RFC7799].

Active OAM:
: Uses dedicated OAM packets.

Passive OAM:
: Relies on the observation of one or more existing data packet streams and does not use dedicated OAM packets and does not modify data packets.

Hybrid OAM:
: Uses a combination of Active Methods and Passive Methods, which may include augmentation or modification of the stream of interest. [RFC7799] makes a distinction between Hybrid Type I, referring to a single stream of interest, and Hybrid Type II, referring to two or more streams of interest.

This document defines the term In-Data-Packet OAM as a more specific and narrowly scoped instance within the broader category of Hybrid OAM. This new term allows for a more fine-grained classification of OAM mechanisms, as the broad category of Hybrid OAM includes a diverse set of possible OAM methods.

In-Data-Packet OAM:

OAM-related information is carried in the packets that also carry the data traffic. This is a specific case of Hybrid OAM. It was sometimes referred to as "in-band".

Note that In-Data-Packet OAM is a specific case of Hybrid Type I, as it is applied to a single stream of interest.

The following examples illustrate the terms Active, Passive, Hybrid, and In-Data-Packet OAM:

* The MPLS echo request/reply messages [RFC8029] are an example of "Active OAM", since they are described as "An MPLS echo request/reply is a (possibly MPLS-labeled) IPv4 or IPv6 UDP packet".

* Monitoring a packet stream by maintaining counters for the packets within the stream is an example of "Passive OAM".

* An example of "Hybrid Type I OAM" that is also "In-Data-Packet OAM", is an IOAM (In Situ OAM) [RFC9197] trace option that is incorporated into data packets of a single stream of interest. According to [RFC9197], IOAM ’...records OAM information within the packet while the packet traverses a particular network domain. The term "in situ" refers to the fact that the OAM data is added to the data packets rather than being sent within packets specifically dedicated to OAM.’

* Another example of "Hybrid Type I OAM" that is also "In-Data-Packet OAM" is Alternate Marking [RFC9341], when applied to data packets of a single stream. In this case a small number of bits in the packet header is used for marking a subset of packets in a flow.

* An example of "Hybrid Type I OAM" which is not classified as "In-Data-Packet OAM" is Direct Loss Measurement [RFC6374], in which user packets are not modified by the protocol. Instead, OAM packets are used for carrying information about observed network characteristics, namely user packet counter values, allowing for packet loss computation.

* Another example of "Hybrid Type I OAM" which is not "In-Data-Packet OAM" is the case where a packet stream is (actively) generated while an existing stream of interest is (passively) observed. This example was introduced in [RFC7799] as a Hybrid Type I method. Extending this example, if the packets of the active stream include an IOAM trace option, the method is characterized by the more general term, Hybrid Type I.

### 3.3. Path Followed OAM

Path-Congruent OAM:
The OAM information follows the exact same forwarding path as the observed data traffic.

Non-Path-Congruent OAM:
The OAM information is not guaranteed to follow the exact same forwarding path as the observed data traffic. This can also be called Path-Incongruent OAM.

In this document, the term "path-congruent packets" describes packets that follow the exact same path (i.e., traverse the same nodes and links) within a network. Note that this definition does not describe how the packets are treated in queues within the nodes on the path.

An example of "Path-Congruent OAM" is the Virtual Circuit Connectivity Verification (VCCV) Type 1 (Section 5.1.1 of [RFC5085]), which was also referred to as In-Band VCCV. The term "congruent" also appears in Section 2 of [RFC6669] in the context of path sharing.

### 3.4. Packet Forwarding Treatment OAM

Equal-Forwarding-Treatment OAM:
The OAM packets receive the same forwarding (e.g., QoS) treatment as user data packets.

Different-Forwarding-Treatment OAM:
The OAM packets might receive different forwarding (e.g., QoS) treatment than user data packets.

The motivation for Equal-Forwarding-Treatment OAM lies in the desire to ensure that OAM packets experience the same network conditions as the user data they are intended to monitor. This includes not only traversing the same topological path but also receiving identical Quality of Service (QoS) treatment, such as queuing, scheduling, and traffic shaping. When both topological and forwarding treatment equivalence are achieved, the OAM packets are said to exhibit fate-sharing [RFC7276] with the data traffic. Fate-sharing ensures that any impairments or anomalies affecting the user traffic are also reflected in the behavior of the OAM packets, thereby making the results of the OAM observations more operationally meaningful and actionable. Without such equivalence, discrepancies in treatment could lead to misleading measurements or diagnostics, and even inadequate corrective actions, reducing the utility of the OAM mechanism for performance monitoring, fault detection and mitigation.

An example of "Equal-Forwarding-Treatment OAM" is presented in [RFC9551] in the context of Deterministic Networking (DetNet) OAM: "it traverses the same set of links and interfaces receiving the same QoS and Packet Replication, Elimination, and Ordering Functions (PREOF) treatment as the monitored DetNet flow".

### 3.5. Using Multiple Criteria

OAM protocols and tools can be classified according to the three criteria that were described in the previous sections. However, not all criteria are applicable to all OAM protocols, and not all combinations are necessarily possible. For example:

* Passive OAM relies solely on observing existing data traffic and does not generate dedicated OAM packets. As such, the path congruence and forwarding treatment criteria are not relevant, since no dedicated OAM packets are exchanged between the measurement points.

* Non-Path-Congruent OAM, by nature, cannot be Equal-Forwarding-Treatment.

When defining a new OAM mechanism or analyzing an existing one, it is recommended to explicitly consider which of these criteria are applicable and to describe the mechanism accordingly. As a first step, all OAM mechanisms can be classified according to the first criterion, as Active, Passive, or Hybrid/In-Data-Packet. Further classification according to the other two criteria should be considered on a case-by-case basis.

A few examples of OAM classification according to the three criteria are presented below:

* IP Ping, which uses ICMP Echo messages, can be classified as Active OAM. Since it is not guaranteed to follow the same path or receive the same treatment as user data packets, it is classified as Non-Path-Congruent and, consequently, as Different-Forwarding-Treatment.

* When an IOAM trace option [RFC9197] is incorporated in data packets it can be classified as In-Data-Packet, Path-Congruent and Equal-Forwarding-Treatment.

* VCCV [RFC5085], as discussed above, is classified as Active, Path-Congruent, and Different-Forwarding-Treatment.

* MPLS Inferred Loss Measurement (ILM) (Section 3 of [RFC6374]) uses specially generated test messages, and therefore can be classified as Active. It is also Path-Congruent, and can be deployed either as Equal- or Different-Forwarding-Treatment OAM. MPLS Direct Loss Measurement (DLM) (Section 3 of [RFC6374]) uses OAM messages that carry counters that count user data traffic. Hence, it is classified as Hybrid Type I OAM, and as in the Inferred Loss Measurement, it is Path-Congruent, and can be either Equal- or Different-Forwarding-Treatment OAM.

In measurement protocols, accurate results depend on path congruence and equal forwarding treatment. In contrast, these properties are not always required in other OAM protocols. For example, Bidirectional Forwarding Detection (BFD) [RFC5880] control packets are often sent with the highest priority, which means they do not adhere to the equal forwarding treatment property.

This multi-dimensional classification enables a more precise and consistent understanding of OAM mechanisms.

### 3.6. Summary of Terms

This section summarizes the terminology:

Active OAM:
Uses dedicated OAM packets.

Passive OAM:
Relies on the observation of one or more existing data packet streams and does not use dedicated OAM packets and does not modify data packets.

Hybrid OAM:
Uses a combination of Active Methods and Passive Methods, which may include augmentation or modification of the stream of interest. [RFC7799] makes a distinction between Hybrid Type I, referring to a single stream of interest, and Hybrid Type II, referring to two or more streams of interest.

In-Data-Packet OAM:
OAM-related information is carried in the packets that also carry the data traffic. This is a specific case of Hybrid OAM. It was sometimes referred to as "in-band".

Path-Congruent OAM:
The OAM information follows the exact same forwarding path as the observed data traffic.

Non-Path-Congruent OAM:
The OAM information is not guaranteed to follow the exact same forwarding path as the observed data traffic. This can also be called Path-Incongruent OAM.

Equal-Forwarding-Treatment OAM:
The OAM packets receive the same forwarding (e.g., QoS) treatment as user data packets.

Different-Forwarding-Treatment OAM:
The OAM packets might receive different forwarding (e.g., QoS) treatment than user data packets.

## 4. Security Considerations

Security is improved when terms are used with precision, and their definitions are unambiguous.

## 5. IANA Considerations

This document has no IANA actions.

## 6. Acknowledgements

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## Appendix A. Examples of the Use of the Term In-Band

This appendix provides a few examples of the use of the term "in-band". These are intended to highlight the varying interpretations of the term across different contexts, which led to the guidelines in this document.

In-Data-Packet OAM was in some cases referred to as "in-band". Initially, "In situ OAM" [RFC9197] was also referred to as "In-band OAM", but was renamed due to the overloaded meaning of "In-band OAM". Further, [RFC9232] also intertwines the terms "in-band" with "in situ". Other similar uses, including [P4-INT-2.1], still use variations of "in-band", "in band", or "inband".

Path-Congruent OAM was sometimes referred to as "in-band". As described in [RFC5085], "The VCCV message travels in-band with the Session and follows the exact same path as the user data for the session". The term "in-band" is also used in Section 2 of [RFC6669] with the same meaning. Non-Path-Congruent OAM was referred to in [RFC5085] as Out-of-Band.

The property of "Equal-Forwarding-Treatment" is referred to in [RFC9551] as "In-band OAM". Similarly, the property of "Different-Forwarding-Treatment OAM" can be found in the following definition in [RFC9551]: "Out-of-band OAM: an active OAM method whose path through the DetNet domain may not be topologically identical to the path of the monitored DetNet flow, its test packets may receive different QoS and/or PREOF treatment, or both." [I-D.ietf-raw-architecture] uses similar text.

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